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Plasmonic Enhancement in SnO_2-based Dye Sensitized Solar Cells

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Extended Abstract

Dye-sensitized solar cells (DSSC) have been recognized as a promising candidate of the emerging solar technology. Titanium dioxide (TiO_2) nanoparticles have been commonly used as the anode material and the host of dye molecules. Recently, researchers have been looking for a better alternative to TiO_2, such as zinc oxide (ZnO) and tin oxide (SnO_2). Compared to TiO_2, SnO_2 typically has two to three times higher electron mobility which is advantageous to the performance of DSSC (Teh et al., 2013; Liu et al., 2013). SnO_2 also has greater bandgap which may allow longer lifetime and better stability of DSSC.

However, the efficiency of SnO_2-based DSSC is typically lower than that of TiO_2 based DSSCs. Commonly reported efficiencies are below 2% (Teh et al., 2013; Liu et al., 2013), with very few exceptions for special morphologies of SnO_2 (Krishnamoorthy et al., 2012). In addition to the synthesis of novel morphologies, other possible methods for the improvement of performance of SnO_2-based DSSCs include the introduction of dopants, the use of novel dyes, ad well as optimization of the device architecture to increase the absorption of light. This last strategy can be implemented either by optimizing the light scattering or by the incorporation of plasmonic elements.

In this study, we investigated the use of plasmonic structures to improve the performance of SnO_2-based DSSCs. Plasmonic structures such as Au nanoparticles and Au/SiO_2 core-shell structures were introduced into SnO_2-based DSSC. The plasmonic structures were directly incorporated into the SnO_2-nanoparticle based paste, which was then processed into the porous layer by doctor-blading and sintering. For all devices, TiO_2 surface modification using titania precursors (titanium(IV) isopropoxide and titanium(IV) chloride) was performed prior to immersion into N719 dye solution to enhance dye adsorption. The active area of cells was 1 x 1 cm^2. Under optimal conditions, the energy conversion efficiency increases 10% from 3.14% (without plasmonic structures) to 3.45% (with plasmonic structures) under AM 1.5 illumination as shown on Table 1. Performance of the solar cells with pure Au and Au/SiO_2 core-shell structures was similar. The I-V characteristics of the solar cells are shown on Figure 1. The major contribution to the increased efficiency is the improved short circuit current. It is likely due to the fact that the plasmonic structures can improve the absorption of light in the solar cell.

Table 1. Properties of the SnO_2-based DSSCs incorporated with Au nanoparticles and Au/SiO_2 core-shell structures.

Sample	V_{OC} (V)	J_{SC} (mA/cm^2)	FF	Efficiency (%)
Control	0.63	9.1	0.55	3.14
Au nanoparticles	0.63	9.8	0.55	3.36
Au/SiO_2 core-shell structures	0.63	9.9	0.55	3.45

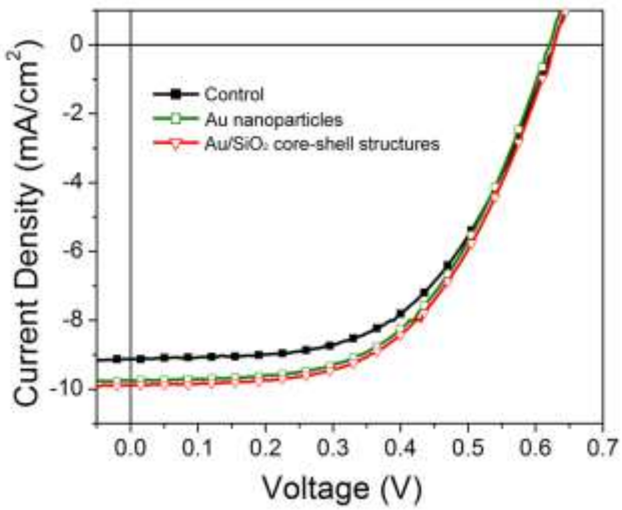

Fig. 1. I-V characteristics of the SnO_2-based DSSCs incorporated with Au nanoparticles and Au/SiO_2 core-shell structures.

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